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INCIDENCE, SEVERITY, AND GROWTH LOSSES ASSOCIATED WITH PONDEROSA PINE DWARF MISTLETOE ON THE COCONINO NATIONAL FOREST, ARIZONA

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INCIDENCE, SEVERITY, AND GROWTH LOSSES ASSOCIATED WITH PONDEROSA PINE DWARF MISTLETOE ON THE COCONINO NATIONAL FOREST, ARIZONA

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By

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ABSTRACT

Forest stands adjacent to 866 miles of forest road were surveyed on the Coconino National Forest in 1984 to determine the incidence and severity of dwarf mistletoe infection in the commercial ponderosa pine forest cover type. The survey data provided a basis for estimating the magnitude of growth losses associated with dwarf mistletoe. Thirty-two percent of the surveyed stands were mistletoe infected. Of the infected stands, 58 percent had less than one-third of the trees in the managed age class infected, 30 percent of the infected stands had one-third to two-thirds of the trees infected, and 12 percent of the stands had more than two-thirds of the trees in the managed age class infected. Forest-wide, 13,859 acres were surveyed; survey miles and acres were distributed proportionally across all stand size and visual quality classes. Chi-square analyses indicated that there were a few significant relationships between stand size classes, visual quality classes, and dwarf mistletoe incidence and severity (P=0.05). On the Elden District, mistletoe was significantly higher in other retention and foreground partial retention stands and lower in foreground retention stands. In the Forest-wide Chi-square analyses, mistletoe incidence in poletimber stands was greater than could be predicted from the Chi-square distribution; the reduced mistletoe incidence in the sawtimber stands was much less than could be predicted from the same distribution.

A previous Region-wide dwarf mistletoe survey, conducted between 1954-57 (Andrews and Daniels 1960), indicated that 30 percent of the ponderosa pine stands on the Coconino National Forest were infected with dwarf mistletoe. Results from the 1984 survey indicate that dwarf mistletoe incidence has increased 2 percent in the last 25 to 30 years.

Total growth losses were estimated using incidence and severity data from the 1984 survey and RMYLD2 growth and yield simulations. When timber management, silviculture, and dwarf mistletoe control were simultaneously optimized in the simulations, the most conservative estimate of annual loss in sawtimber at the current level of incidence was 9.8 MMBF per year. The corresponding annual loss estimate in pulpwood yield was 2.0 MMCF per year. Small changes in data input into RMYLD2 reflecting changes in timber management emphasis (i.e., focus on nontimber resource objectives), silvicultural prescriptions, and dwarf mistletoe control cutting methods produced large increases in the annual loss estimates. We estimate the annual losses in sawtimber and pulpwood growth and yield to be 20 to 30 MMBF and 6 to 8 MMCF, respectively.

INTRODUCTION

Rocky Mountain ponderosa pine (Pinus ponderosa var. scopulorum Engelm.) grows on an estimated 11 million acres in the Southwestern United States. In Arizona and New Mexico, 2.5 million acres are regarded as being commercially productive (growth $\geq$20 ft^3 per acre per year). On the Coconino National Forest, 92 percent of the acres of commercial timberland are in the ponderosa pine forest cover type, accounting for an equivalent proportion of the annual harvest volume for this Forest.

Region-wide, over one-third (36%) of the commercial ponderosa pine resource is dwarf mistletoe infected (Arceuthobium vaginatum subsp. cryptopodum (Engelm.) Hawks. and Wiens); by Forest, estimates of infection levels range from 15 percent to nearly 65 percent (Andrews and Daniels 1960). Volume losses associated with ponderosa pine dwarf mistletoe are primarily growth losses. By comparison, losses caused by other important disease pests of ponderosa pine, most notably the root rot pathogens Armillaria mellea and Heterobasidion annosum, are related to tree mortality.

The apparent increase in incidence and severity of dwarf mistletoe in southwestern ponderosa pine has been of particular concern to forest pathologists. Observations suggest that stands with histories of repeated selective harvest exhibit the greatest increase in dwarf mistletoe infection severity; data to confirm or disprove this contention have been lacking. The objectives of this evaluation were to: (1) Compare present dwarf mistletoe incidence in the ponderosa pine forest cover type with that found in the 1954-57 survey on the Coconino National Forest, (2) determine if changes in dwarf mistletoe incidence and severity are related to stand size class or visual quality classifications, and (3) estimate annual growth losses caused by ponderosa pine dwarf mistletoe by Ranger District and Forest-wide.

METHODS

Roadside Survey. This evaluation used the survey methods of Andrews and Daniels (1960), Merrill et al. (1985), and Johnson et al. (1984). Roadside survey-sampling methods were deemed appropriate to this problem analysis, since the spread of dwarf mistletoe is not correlated with the presence or impact of forest roading.

The survey determined dwarf mistletoe incidence and severity by combinations of forest cover type, stand size class, and visual quality class. All passable National Forest System roads on each Ranger District were surveyed. Mistletoe data were collected only from acres of ponderosa pine classified as tentatively suitable in the land management planning process. Forest cover type and stand size class of stands adjacent to roads were determined from land management

planning forest cover type maps. The 16 original stand condition classes (FSH 2409.26d, dated November 1975) were condensed for simplification to form 5 broader stand size classes:

Seedlings and saplings (SS); combining 01, 14, and 15
(>4 inches tall; <5.0 inches d.b.h.)

Poletimber (PT); combining 02, 04, 06, 08, 10, and 12
(5.0 to 8.9 inches d.b.h.)

Sawtimber (ST); combining 03, 05, 07, 09, and 13
(9.0 inches and larger)

Overmature timber (OT); 11
(old growth)

Nonstocked (NS); 16

Sensitivity levels and visual quality objectives (FSH 2383.1; Agriculture Handbook No. 462; FSH 2383.16) were combined to reduce the number of classes, since management practices do not change significantly between some levels. The seven combined classes were:

1. Foreground retention (FR)
2. Other retention (OR)
3. Foreground partial retention (FPR)
4. Level 3 partial retention (3PR)
5. Other partial retention (OPR)
6. Level 3 modification (3M)
7. Other modification (OM)

Visual resource inventory maps (scale 2.64 or 2.0 inches=1 mile) were used to indicate current boundaries of visual quality classes. Changes in forest cover type, stand size class, and visual quality class were clearly marked on survey maps and those maps are archived as a permanent record of the survey. Two-person crews drove selected roads at speeds not exceeding 10 miles per hour and observed a strip 2 chains wide, measured from the edge of the right-of-way, parallel to the right side of the road. Changes in forest cover type, stand size class, visual quality class, and dwarf mistletoe infection severity were visually estimated and recorded to the nearest 0.10 mile using

the survey vehicles' odometer. Dwarf mistletoe (DM) infection severity was measured as follows:

DM0=No visible infestation in stands.

DM1=Less than one-third of the trees in the managed age class infected.

DM2=One-third to two-thirds of the trees in the managed age class infected.

DM3=More than two-thirds of the trees in the managed age class infected.

At the beginning of the survey, transects 1 chain wide by 2 chains long, perpendicular to the road axis, were established every mile in which infected and uninfected trees in the managed age class were tallied to correct ocular estimates of infection severity. The number of transects gradually decreased as survey crews developed expertise in estimating infection severity.

Survey results were expressed as the ratio of miles traveled adjacent to infected stands to the total miles traveled Forest-wide, by District, stand size class, visual quality class, and dwarf mistletoe infection severity level. A record of the roads surveyed and direction traveled for each road can be found in Figures 6-10 of the Appendix.

Growth Loss Estimations. If all stands on the Forests were mistletoe free, that would represent full volume productivity or potential. It is not now, nor will it ever be, feasible to reach the mistletoe free state. It is feasible, however, to reduce mistletoe infection severity in stands so that impact on full volume productivity is negligible. The comparison of full productive potential to existing conditions is useful for assessing the magnitude of the problem. In generating sawtimber and pulpwood volume loss estimates, stands representative of the four forested stand size classes (i.e., seedlings and saplings, poletimber, sawtimber, and overmature timber) were projected to rotation age (120 years) using RMYLD2 (Edminster 1978) at the midpoint of each of the four infection severity levels.

Each stand size class was assigned a nominal age:

Seedlings and saplings	= 20 years
Poletimber	= 50 years
Sawtimber	= 100 years
Overmature timber	= 200 years

Site index values of 60, 70, and 80 feet (100-year index age) were used in the growth and yield simulations to reflect the range of conditions extant on the Forest. Growing stock levels (GSL's) were adjusted whenever possible to reflect site productivity, optimize volume production and product size, and achieve effective dwarf mistletoe control. Differences in yield for stands managed to rotation at each infection severity level represented the impact on volume production attributable to dwarf mistletoe. RMYLD2 output was expressed in yields per acre; losses were assessed by subtracting infected from healthy stand yields. Losses are reported for each District surveyed by stand size class. Acres of tentatively suitable forest land by forest cover type and stand size class were obtained for the Forest from the 1979 Regional assessment and were also extrapolated from the survey. From the 1979 assessment, the total acres of commercial ponderosa pine = 631,738 acres.

Commercial acres by stand size class (percentages based on survey extrapolations):

Seedlings and saplings	=	82,126 acres (13%)
Poletimber	=	334,821 acres (53%)
Sawtimber	=	202,156 acres (32%)
Overmature timber	=	12,635 acres (2%)
Nonstocked	=	6,317 acres (1%)

Seedling, sapling, and poletimber stands were managed to a 120-year rotation age beginning at 20 and 50 years, respectively. For the sawtimber and overmature timber stands, future growth losses to dwarf mistletoe were considered minor; since stand regeneration was imminent for these stands, the understory component was managed to rotation on RMYLD2. For the sawtimber stands, the seedling and sapling stand size class was simulated; for the overmature timber stands, the poletimber stand size class was simulated. The underlying assumption used in sawtimber and overmature timber simulations was equivalent infection levels in the overstory and understory components. Optimum silvicultural prescriptions by site index, stand size class, and dwarf mistletoe infection severity level are shown in Tables 1 and 2.

For all RMYLD2 simulations, dwarf mistletoe infection severity levels were set at the midpoint of their range:

DM0 = 0 percent infection = PINF 0 ; DMLEV=3.0

DM1 = 16.5 percent infection = PINF 16.5; DMLEV=3.0

DM2 = 49.5 percent infection = PINF 49.5; DMLEV=3.0

DM3 = 82.5 percent infection = PINF 82.5; DMLEV=6.0

(PINF is the equivalent RMYLD2 input variable)

To arrive at estimates of potential volume production for DM3 = 82.5 percent infection, DMLEV was set at 6.0 (DMLEV is the input variable in RMYLD2 that indicates the dwarf mistletoe rating (DMR) above which thinnings will not be performed (Edminster 1978; Hawksworth 1977)).

RESULTS

Dwarf mistletoe was found in 32 percent of the ponderosa pine stands on the Coconino National Forest (Figure 1). Of the 866.2 miles surveyed, 279 miles were mistletoe infected. A total of 13,859 acres were surveyed, equal to a 2.2-percent sampling intensity. Dwarf mistletoe incidence and severity were beneath the Regional average. Table 3 shows dwarf mistletoe incidence and severity by stand size class and District. Mistletoe incidence was greatest on the Blue Ridge and Long Valley Districts and least on the Beaver Creek and Mormon Lake Districts. The Sedona District was not surveyed because of the lack of tentatively suitable acres. Table 4 shows mistletoe infection severity combining all stands in each District; it is a condensation of Table 3. On the Blue Ridge and Long Valley Districts, 48 percent of all stands were mistletoe infected, but 65 and 59 percent of these infected stands were less than one-third infected, respectively (Figure 1). On the Blue Ridge District, 47 percent of the seedling and sapling stands were infected with mistletoe, forewarning significant problems in the future. Similarly, 45 percent of the poletimber stands and 49 percent of the sawtimber stands were mistletoe infected. Forest-wide, the trend in sawtimber stands was toward reduced mistletoe infection severity (Table 3). In poletimber stands, mistletoe incidence and severity have increased appreciably (Figure 2). On the Beaver Creek District, only 12 percent of the stands were infected and most all of these were in poletimber.

Table 5 shows dwarf mistletoe incidence by visual quality class, and Table 6 gives incidence by visual quality class and infection severity level. Mistletoe was evenly distributed with respect to visual quality classes on the Mormon Lake District. On the Flagstaff District, mistletoe incidence was greatest in stands of any age that were classified as level 3 modification. On the Elden District, mistletoe incidence was highest in other retention and foreground

partial retention stands of any age and infection severity is increasing (Table 6). Dwarf mistletoe incidence was near 50 percent on both the Blue Ridge and Long Valley Disticts; timber stands in the foreground retention and foreground partial retention classes were most heavily infected on the Blue Ridge District; other partial retention stands had the highest incidence on the Long Valley District. The data presented on Table 6 suggest that dwarf mistletoe incidence and severity are increasing on the Blue Ridge and Long Valley Districts and parts of the Elden and Mormon Lake Districts.

Chi-square analyses, comparing observed and expected mistletoe infection levels by stand size and visual quality classes, revealed several significant (P=0.05) relationships (Table 7 and Figures 2 and 3). On the Elden District, mistletoe incidence was significantly less in foreground retention stands, and significantly greater in other retention and foreground partial retention stands (Figure 3). Forest-wide, dwarf mistletoe incidence in sawtimber stands was less than predicted from the Chi-square distribution (Figure 2). Mistletoe incidence in poletimber stands was significantly greater than would be expected. Dwarf mistletoe incidence was less than predicted in foreground retention stands and greater in foreground partial retention and level 3 modification stands (Table 7).

Estimates of annual growth loss by District are summarized in Table 8. These estimates are not based on simulating current management conditions, but are an expression of growth losses to dwarf mistletoe under the best circumstances, when silviculture and dwarf mistletoe control are optimized coincidentally and all infected stands are entered immediately. A sawtimber-loss estimate of 9.8 MMBF per year, Forest-wide, is the most conservative estimate when mistletoe incidence is 32 percent (Figure 4). Since all stands cannot be entered immediately, current sawtimber losses on the Coconino National Forest exceed 20 MMBF per year and may run as high as 30 MMBF per year. This is confirmed in yield projections that allow delayed entry. A comparable inflation applies to cubic foot volume losses as well (i.e., 6-8 MMCF per year).

Based on the results of their 1954-57 mistletoe survey, Andrews and Daniels (1960) concluded that 30 percent of the commercial ponderosa pine stands on the Coconino National Forest were infected with dwarf mistletoe. These estimates were based on a plot survey; 310 plots were taken on the Forest. We analyzed the unpublished data from their roadside survey, from that same period, and found that it corroborated the results of their plot survey for the Districts they surveyed. We feel that the older plot and roadside survey information is accurate and it serves as an appropriate yardstick upon which to evaluate the results of this current survey. Dwarf mistletoe incidence has increased from 30 to 32 percent in 25 to 30 years on the Coconino National Forest (Figure 5).

DISCUSSION

The results of the 1984 dwarf mistletoe survey indicate a trend of increasing incidence and severity. We attribute the increased incidence to 25 or more years of selective harvesting. The propensity to prescribe preparatory cuts in succession, where seed cuts or final removals were needed, has perpetuated unevenaged stand conditions and increased the rate of spread of the disease. Past management emphasis was inappropriate to reducing dwarf mistletoe; cutting out the volume was most important. Trees that were selected for harvest were scattered throughout stands and usually were the largest and healthiest individuals. What remained after each selective harvest was a higher proportion of inferior quality, mistletoe-infected trees. Openings created by selective removals were naturally regenerated, stands were unevenaged and multistoried, and dwarf mistletoe spread quickly into the new understory. We surmise that a portion of the increase in dwarf mistletoe incidence is real increase (i.e., new infection of previously healthy trees), but perhaps an equally important portion is that which has resulted from increasing the diseased proportion in stands by selective harvesting.

The increased incidence and severity of dwarf mistletoe infection on the Coconino National Forest is significant, especially since the level of incidence is easily regulated, in most cases, with appropriate cutting methods. Management objectives in the future should reflect a concerted effort to reduce dwarf mistletoe effects on growth and yield. Unchecked, the mistletoe problem will worsen and the magnitude of associated growth losses will increase. The trend can be reversed through improvement in silvicultural treatments.

In general, dwarf mistletoe spreads most slowly in single-story, even-aged stands of any age. Small departures from even-aged management result in radical increases in dwarf mistletoe incidence and severity. In the RMYLD2 growth and yield simulations that were used to estimate volume losses, stocking was drastically reduced in infected stands at the earliest possible time to reduce stand DMR's. Without this early reduction in stocking, stands were destroyed by dwarf mistletoe before rotation age. Volume loss estimates assume that thinning entries or regeneration cuts were made in every stand at the most opportune time. Departures from this management strategy resulted in reductions in timber yield much worse than reported here.

In addition to documenting mistletoe incidence, severity, and associated growth losses, it is intended that these survey results will draw to a focus the scope and principal causes of the problem, so that corrective timber management decisions can be made to reverse the trend of increasing mistletoe severity on the Forests.

The principal causes as we see them are:

1. A repeated history of selective harvesting in dwarf mistletoe-infected stands.

2. Silvicultural prescriptions that perpetuated unevenaged stand conditions. The ponderosa pine cover type consisted of a mosaic of unevenaged clumps of trees. Following selective overstory removals, portions of every stand were naturally regenerated. Seed cuts were rare and total overstory removals almost nonexistent.

3. Lack of priority given to treating mistletoe-infected stands. Entire timber sale areas were selectively harvested to produce a targeted volume. Little thought was given to delineating specific cutting units for the primary purpose of controlling dwarf mistletoe. By giving mistletoe-infected stands high treatment priority in timber sales, two major works could be accomplished: (a) The targeted volume could be realized from fewer acres and (b) greater volume would be produced in properly treated stands that could be harvested in subsequent entries.

4. Ineffective cutting methods when dwarf mistletoe was the intended object of silvicultural prescriptions. Visibly infected overstory trees were removed, but trees with little evidence of witches' broom formation were retained in the overstory. Seeds discharged from mistletoe plants in the residual overstory trees provided the inoculum source for further overstory and understory infections. In most cases, a seed cut and overstory removal, followed by judicious thinning in the understory, would have reduced the presence of the dwarf mistletoe in stands to acceptable levels.

5. Lack of a consistent approach or policy for controlling dwarf mistletoe in stands of all sizes. Table 3 shows the breakdown of dwarf mistletoe infection severity by size class; Table 7 indicates those increments and decrements that are significant. In Table 3, mistletoe incidence in seedling and sapling stands approximately equals Forest-wide mistletoe incidence. Incidence in sawtimber stands is much less than the Forest-wide estimate. Statistical analysis indicates that the reduction in mistletoe incidence in sawtimber stands is significantly greater than could be predicted. Timber entries have reduced the dwarf mistletoe incidence in sawtimber stands. Of greatest importance is the level of mistletoe incidence in poletimber Forest-wide; mistletoe incidence is much greater in poletimber than would normally be expected. Since one-half of the commercial land base for the Forest is in poletimber stands (see page 6), a considerable proportion of the future volume production is expected to be generated by these stands. Without proper control, that volume cannot be realized. Two-thirds of the commercial land base for the Forest is in seedling, sapling, and poletimber stands; 35 percent of these stands are currently mistletoe infected.

6. Lack of an effective policy for controlling dwarf mistletoe in visually sensitive areas. Table 6 shows the breakdown of dwarf mistletoe infection severity by visual quality class; Table 7 indicates those increments and decrements that are significant. The most visually sensitive visual quality class and least impacted by timber management entries is the foreground retention class. We might

expect that dwarf mistletoe incidence in these stands would be greatest because they are not entered for management to retain their visual integrity. On the contrary, dwarf mistletoe incidence is lowest in foreground retention stands. We surmise that the lack of timber management entries in these stands has reduced or eliminated the potential for mistletoe enhancement by selective harvesting. In the foreground partial retention visual quality class, where visual sensitivity is of considerable importance, dwarf mistletoe incidence consistently exceeds the Forest-wide level. Timber entries are allowed in these stands, but timber harvesting methods that will effectively control dwarf mistletoe are not utilized at the Forest level because they are considered visually unacceptable.

The growth losses estimated and presented reflect the level of damage and loss associated with mistletoe at the present level of incidence. Losses will decrease with reductions in the number and distribution of infected trees in stands. The solution to the problem lies in improving stand management by treating infected stands first, thereby reducing mistletoe incidence in stands, one stand at a time. It is important that mistletoe incidence routinely becomes a major decision variable when stand treatments are prioritized and cutting units are selected in timber sales. Prescriptions need to reflect a major emphasis of reducing stand DMR, while trying to reflect stocking, spacing, and tree diameter objectives. Dwarf mistletoe is endemic in southwestern ponderosa pine forests, but its impact can be reduced with proper management so that the effects are negligible.

Chapter 70 in the Cutting Methods Handbook (FSH 2409.26a, dated December 1984) was prepared as a field aid for dealing with mistletoe-infected stands. Information is given on rating infected trees and whole stands, and methods are presented which aid in the complex process of determining which cutting units should be entered and which can be deferred. Sections on regeneration and intermediate cutting methods are also included. Much of the time these materials will provide the necessary guidance. If additional technical assistance is needed, pathologists in the Regional Office are available to help evaluate mistletoe problems and assist in formulating prescriptions to control dwarf mistletoe in specific cutting units.

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APPENDIX

TABLE 1.--Optimum prescriptions for RMYLD2 growth and yield simulations for the Coconino National Forest seedlings and saplings (SS)

SSC[1]	AGE (yrs)	SITE INDEX	DMR[4] START (0-6)	PINF[4] START %	DMR[5] FINAL (0-6)	THIN1[4] (GSL)	DSTY1[4] (GSL)	DSTY2[4] (GSL)	DBH[5] CUT (in)	DBH[5] RESID. (in)	VOLUME OUT[5] MBF/AC	VOLUME OUT[5] MCF/AC	CULM. MAI[3] AGE (yrs)	CULM. MAI[3] ft^3
SS	20	60	0	0	0	60	60	60	19.1	16.6	15.1	3.5	100	27
			0.2	16.5	0.4	40	40	40	21.7	19.7	11.8	2.8	90	22
			0.7	49.5	0.1	20	40	40	21.9	19.7	10.9	2.5	90	19
(Regenerate)[2]			2.6	82.5	6.0	20	20	20	21.4	21.3	0.6	0.1	70	8
SS	20	70	0	0	0	60	70	70	19.3	16.7	20.3	4.6	100	36
			0.2	16.5	0.1	40	60	60	20.4	17.8	17.6	4.0	100	31
			0.7	49.5	0.4	40	40	40	22.9	20.7	13.7	3.2	90	25
(Regenerate)[2]			2.6	82.5	5.5	20	20	20	23.5	23.4	4.0	1.0	80	12
SS	20	80	0	0	0	60	70	70	20.5	18.0	25.2	5.6	100	43
			0.2	16.5	0.1	40	60	60	21.4	19.1	21.9	4.8	100	37
			0.7	49.5	0.3	40	50	50	22.6	20.3	19.4	4.3	90	33
(Regenerate)[2]			2.6	82.5	4.8	20	20	20	26.2	25.8	7.8	1.7	80	15

[1]SSC is stand size class.
[2]Unable to reduce dwarf mistletoe to acceptable levels; regenerate the stand.
[3]Culmination of mean annual increment.
[4]Input variables for data entry into RMYLD2; DMR START=DMR(1) stand dwarf mistletoe rating; PINF START=PINF(1) percent mistletoe infected; THIN1=growing stock level achieved with initial thinning; DSTY1 and 2=growing stock level or density achieved with subsequent entries. (Edminster 1978).
[5]Output from RMYLD2; DMR FINAL=stand dwarf mistletoe rating at rotation; DBH CUT=average diameter of sawtimber cut during the seed cut; DBH RESID.=average residual seed tree diameter; VOLUME OUT=commercial volume produced per acre.

TABLE 2.--Optimum prescriptions for RMYLD2 growth and yield simulations for the Coconino National Forest poletimber (PT)

SSC[1]	AGE (yrs)	SITE INDEX	DMR[4] START (0-6)	PINF[4] START %	DMR[5] FINAL (0-6)	THIN1[4] (GSL)	DSTY1[4] (GSL)	DSTY2[4] (GSL)	DBH[5] CUT (in)	DBH[5] RESID. (in)	VOLUME OUT[5] MBF/AC	VOLUME OUT[5] MCF/AC	CULM. MAI.[3] AGE (yrs)	CULM. MAI.[3] ft³
PT	50	60	0	0	0	60	60	60	19.5	16.8	14.8	3.4	120	25
			0.2	16.5	0.1	40	50	50	19.3	16.7	12.1	3.1	110	22
			0.7	49.5	0.1	40	50	50	19.3	16.7	12.1	3.1	110	22
(Regenerate)[2]			2.6	82.5	4.5	20	20	20	22.3	21.7	4.9	1.5	50	12
PT	50	70	0	0	0	60	70	70	20.0	17.5	19.6	4.4	110	31
			0.2	16.5	0.1	40	60	60	19.5	16.9	16.7	4.0	110	29
			0.7	49.5	0.1	40	60	60	19.5	16.9	16.7	4.0	110	29
(Regenerate)[2]			2.6	82.5	3.9	20	20	20	23.5	22.9	7.0	2.2	70	17
PT	50	80	0	0	0	60	70	70	21.6	19.4	24.1	5.4	100	38
			0.2	16.5	0.1	40	60	60	20.5	18.1	20.0	5.1	110	37
			0.7	49.5	0.1	40	60	60	20.5	18.1	20.0	5.1	110	37
(Regenerate)[2]			2.6	82.5	2.8	20	30	30	23.1	21.7	11.6	3.4	50	26

[1]SSC is stand size class.
[2]Unable to reduce dwarf mistletoe to acceptable levels; regenerate the stand.
[3]Culmination of mean annual increment.
[4]Input variables for data entry into RMYLD2; DMR START=DMR(1) stand dwarf mistletoe rating; PINF START=PINF(1) percent mistletoe infected; THIN1=growing stock level achieved with initial thinning; DSTY1 and 2=growing stock level or density achieved with subsequent entries. (Edminster 1978).
[5]Output from RMYLD; DMR FINAL=stand dwarf mistletoe rating at rotation; DBH CUT=average diameter of sawtimber cut during the seed cut; DBH RESID.=average residual seed tree diameter; VOLUME OUT=commercial volume produced per acre.

TABLE 3.--Dwarf mistletoe infection severity estimates by stand size class for Districts on tne Coconino National Forest

RANGER DISTRICT		STAND SIZE CLASS															
		SEEDINGS/SAPLINGS				POLETIMBER				SAWTIMBER				OVERMATURE			
		0	1	2	3[1]	0	1	2	3	0	1	2	3	0	1	2	3
BLUE RIDGE	MI[2]	23.2	17.8	2.4	0.1	20.8	7.1	7.5	2.1	11.1	5.2	4.4	1.0	2.4	3.8	0.8	0
	%[3]	53	41	6	0	55	19	20	6	51	24	20	5	34	54	12	0
LONG VALLEY	MI	10.1	5.6	2.1	0.3	36.8	23.0	14.4	2.4	21.4	9.3	6.6	0.7	2.6	0.2	0	0
	%	56	31	12	2	48	30	19	3	56	25	17	2	93	7	0	0
FLAGSTAFF	MI	18.0	3.7	1.8	0.7	120.2	29.1	14.0	14.1	34.6	8.3	4.5	1.8	0.3	0.4	0	0
	%	75	15	7	3	68	16	8	8	70	17	9	4	43	57	0	0
ELDEN	MI	7.0	1.7	0	0.1	20.9	6.0	3.8	1.6	35.4	1.8	2.2	3.5	0.6	0.4	0	0
	%	80	19	0	1	65	19	12	5	83	4	5	8	60	40	0	0
MORMON LAKE	MI	12.9	2.3	0.7	0.2	97.9	18.8	9.9	1.1	95.8	15.2	7.5	1.1	0.8	1.5	0.2	0
	%	80	14	5	1	77	15	8	1	80	13	6	1	32	60	8	0
BEAVER CREEK	MI	0.3	0	0	0	4.1	0.2	0.3	0.2	1.4	0	0	0.1	0	0	0	0
	%	100	0	0	0	85	4	7	4	93	0	0	7	0	0	0	0
FOREST TOTAL	MI	71.5	31.1	7.0	1.4	300.7	84.2	49.9	21.5	199.7	39.8	25.2	8.2	6.7	6.3	1.0	0
	%	65	28	6	1	65	19	11	5	73	15	9	3	48	45	7	0

[1]Dwarf mistletoe infection severity level.
[2]Miles of road surveyed in stands of a particular size class and infection severity level.
[3]Percentages are computed within the stand size class for a single District, and are rounded up to nearest whole percentage.

TABLE 4.--Comparison of dwarf mistletoe infection severity levels between Districts on the Coconino National Forest

RANGER DISTRICT		DWARF MISTLETOE INFECTION SEVERITY					
		DM(-)[1]	DM(+)[2]	DM1[5]	DM2[5]	DM3[5]	SUBTOTAL
BLUE RIDGE	MI[6]	57.5	52.2	33.9	15.1	3.2	109.7[3]
	%[7]	52	48	31	14	3	13[4]
LONG VALLEY	MI	70.9	64.6	38.1	23.1	3.4	135.5[3]
	%	52	48	28	17	3	16[4]
FLAGSTAFF	MI	175.3	79.0	41.5	20.9	16.6	254.3[3]
	%	69	31	16	8	7	29[4]
ELDEN	MI	63.9	21.1	9.9	6.0	5.2	85.0[3]
	%	75	25	11	7	6	10[4]
MORMON LAKE	MI	214.3	60.8	37.8	18.3	4.7	275.1[3]
	%	78	22	14	7	2	32[4]
BEAVER CREEK	MI	5.8	0.8	0.2	0.3	0.3	6.6[3]
	%	88	12	3	5	5	1[4]
FOREST TOTAL	MI	587.7	278.5	161.4	83.7	33.4	866.2
	%	68	32	19	10	4	100

[1]Miles of ponderosa pine stands surveyed without dwarf mistletoe infection.
[2]Miles of ponderosa pine stands surveyed with dwarf mistletoe infection of severity level (1, 2, or 3).
[3]Miles surveyed in a District.
[4]Percentage of Forest-wide survey miles.
[5]Dwarf mistletoe infection severity level.
[6]Miles surveyed in stands within a District and infection severity level.
[7]Percentage of total miles surveyed in a District within an infection severity level.

TABLE 5.--Dwarf mistletoe incidence by visual quality class for Districts on the Coconino National Forest

RANGER DISTRICT	DM	FR[1]		OR[1]		FPR[1]		3PR[1]		OPR[1]		3M[1]		OM[1]		SUBTOTAL	
		(-)[2]	(+)[3]	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
BLUE RIDGE	MI[4]	8.1	11.8			3.2	8.6	6.4	0.4			39.8	31.4			57.5	52.2
	%[5]	41	59			27	73	94	6			56	44			52	48
LONG VALLEY	MI	4.3	2.9			4.4	4.6	0.3	0	1.9	7.6	59.6	49.5	0.4	0	70.9	64.6
	%	60	40			49	51	100	0	20	80	55	45	0	0	52	48
FLAGSTAFF	MI	11.0	3.1	20.8	5.8	0.5	0	0.3	0	75.6	32.7	65.6	37.1	1.5	0.3	175.3	79.0
	%	78	22	78	22	100	0	100	0	70	30	64	36	83	17	69	31
ELDEN	MI	14.8	0.7	11.2	7.9	1.9	3.9	3.7	0	22.9	8.6	9.4	0			63.9	21.1
	%	95	5	59	41	33	67	100	0	73	27	100	0			75	25
MORMON LAKE	MI	34.4	4.6	0.2	0	4.2	0			6.5	2.2	168.6	54.0	0.3	0	214.2	60.8
	%	88	12	100	0	100	0			75	25	76	24	100	0	78	22
BEAVER CREEK	MI	1.6	0									4.2	0.8			5.8	0.8
	%	100	0									84	16			88	12
FOREST TOTAL	MI	74.2	23.1	32.2	13.7	14.2	17.1	10.7	0.4	106.9	51.1	347.2	172.8	2.2	0.3	587.6	278.5
	%	76	24	70	30	46	54	96	4	68	32	67	33	88	12	68	32

[1]Visual quality classes (see page 4 for an explanation of abbreviations).
[2]Surveyed stands without dwarf mistletoe infection.
[3]Surveyed stands with dwarf mistletoe infection of severity level 1, 2, or 3.
[4]Miles of road surveyed in stands within a District, in a given visual quality class.
[5]Percentage of total miles of road surveyed within a District, in a given visual quality class.

TABLE 6.--Comparison of dwarf mistletoe infection severity estimates by visual quality class for Districts on the Coconino National Forest

RANGER DISTRICT	DM	FR[1]				OR[1]				FPR[1]				3PR[1]				OPR[1]				3M[1]				0M[1]			
		0	1	2	3[2]	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
BLUE RIDGE	MI[3]	8.1	6.5	4.8	0.5					3.2	4.8	3.1	0.7	6.4	0.4							39.8	22.2	7.2	2.0				
	%[4]	41	33	24	3					27	41	26	6	94	6							56	31	10	3				
LONG VALLEY	MI	4.3	1.1	1.8						4.4	2.5	2.0	0.1	0.3				1.9	2.6	4.1	0.9	59.6	31.9	15.2	2.4	0.4			
	%	60	15	25						49	28	22	1	100				20	27	43	9	55	29	14	2	100			
FLAGSTAFF	MI	11.0	2.3	0.4	0.4	20.8	3.2	1.9	0.7	0.5				0.3				75.6	18.9	6.8	7.0	65.6	17.0	11.6	8.5	1.5	0.1	0.2	
	%	78	16	3	3	78	12	7	3	100				100				70	17	6	6	64	17	11	8	83	6	11	
ELDEN	MI	14.8	0.4		0.3	11.2	3.2	1.8	2.9	1.9	2.3	1.2	0.4	3.7				22.9	4.0	3.0	1.6	9.4							
	%	95	3		2	59	17	9	15	33	40	21	7	100				73	13	10	5	100							
MORMON LAKE	MI	34.4	2.7	1.4	0.5	0.2				4.2								6.5	0.9	1.2	0.1	168.6	34.2	15.7	4.1	0.3			
	%	88	7	4	1	100				100								75	10	14	1	76	15	7	2	100			
BEAVER CREEK	MI	1.6																				4.2	0.2	0.3	0.3				
	%	100																				84	4	6	6				
FOREST TOTAL	MI	74.2	13.0	8.4	1.7	32.2	6.4	3.7	3.6	14.2	9.6	6.3	1.2	10.7	0.4			106.9	26.4	15.1	9.6	347.2	105.5	50.0	17.3	2.2	0.1	0.2	
	%	76	13	9	2	70	14	8	8	45	31	20	4	96	4			68	17	10	6	67	20	10	3	88	4	8	

[1]Visual quality class (see page 4 for an explanation of abbreviations).
[2]Dwarf mistletoe infection severity level.
[3]Miles of road surveyed in stands within Districts, visual quality classes, and infection severity levels.
[4]Percentage of total miles surveyed within a District and visual quality class.

TABLE 7.--Summary of Chi-square analyses comparing observed and expected mistletoe incidence[1] by stand size classes and visual quality classes (P=0.05)

		STAND SIZE CLASSES				VISUAL QUALITY CLASSES						
RANGER DISTRICT		SS[3]	PT[3]	ST[3]	OT[3]	FR[4]	OR[4]	FPR[4]	3PR[4]	OPR[4]	3M[4]	OM[4]
BLUE RIDGE (O_i-E_i)	MI[5]	-0.6	-1.3	+0.2	+1.2	+2.2		+2.9	-2.9		-2.8	
	SIG.[2]	NS	NS	NS	NS	NS		NS	NS		NS	
LONG VALLEY	MI	-0.6	+3.0	-1.6	-1.1	-0.6		+0.3	-0.1	+0.3	-2.9	-0.2
	SIG.	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS
FLAGSTAFF	MI	-1.3	+2.2	-0.6	+0.2	-1.3	-2.4	-0.2	-0.1	-0.9	+5.3	-0.3
	SIG.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
ELDEN	MI	-0.4	+3.3	-3.2	+0.1	-3.2	+3.1	+2.4	-0.9	+0.7	-2.4	
	SIG.	NS	NS	NS	NS	S	S	S	NS	NS	NS	
MORMON LAKE	MI	-0.3	+3.5	-2.5	+1.1	-4.0		-0.9		+0.3	+5.1	-0.1
	SIG.	NS	NS	NS	NS	NS		NS		NS	NS	NS
BEAVER CREEK	MI		+0.4	-0.1		-0.2					+0.3	
	SIG.		NS	NS		NS					NS	
FOREST TOTAL	MI	+4.0	+11.2	-14.1	+2.8	-8.0	-0.9	+7.1	-3.2	+0.5	+6.4	-0.5
	SIG.	NS	S	S	NS	S	NS	S	NS	NS	S	NS

[1]Dwarf mistletoe incidence is presented as miles of stands surveyed with any mistletoe infection, by stand size class, visual quality class, and District.
[2]Denotes significance at P=0.05; NS is not significant; S is significant.
[3]SS=seedling and sapling stands; PT=poletimber stands; ST=sawtimber stands; OT=overmature stands.
[4](See page 4 for an explanation of abbreviations).
[5]Difference between the observed (O_i) number of miles of road surveyed with mistletoe infection and the expected (E_i) number of miles with mistletoe infection as predicted by the Chi-square distribution.

TABLE 8.--Minimum estimate[1] of annual losses in sawtimber and pulpwood production on the Coconino National Forest

RANGER DISTRICT		SEEDLINGS AND SAPLINGS (SS) MMBF/YR	SEEDLINGS AND SAPLINGS (SS) MMCF/YR	POLETIMBER (PT) MMBF/YR	POLETIMBER (PT) MMCF/YR	SAWTIMBER (ST) MMBF/YR	SAWTIMBER (ST) MMCF/YR	OVERMATURE TIMBER (OT) MMBF/YR	OVERMATURE TIMBER (OT) MMCF/YR	SUBTOTAL MMBF/YR	SUBTOTAL MMCF/YR
BLUE RIDGE	VOL.	0.2	.0+	1.0	0.2	0.6	0.1	.0+	.0+	1.8	0.3
	%[1]	11	0	56	67	33	33	0	0	18	15
LONG VALLEY	VOL.	0.2	0.1	1.2	0.2	0.6	0.1	.0+	.0+	2.0	0.4
	%	10	25	60	50	30	25	0	0	21	20
FLAGSTAFF	VOL.	0.3	0.1	2.1	0.4	1.0	0.3	0.1	.0+	3.5	0.8
	%	9	12	60	50	29	38	3	0	36	40
ELDEN	VOL.	0.1	.0+	0.3	0.1	0.3	0.1	.0+	.0+	0.7	0.2
	%	14	0	43	50	43	50	0	0	7	10
MORMON LAKE	VOL.	0.2	0.1	0.9	0.1	0.5	0.1	0.1	.0+	1.7	0.3
	%	12	33	53	33	29	33	6	1	17	16
BEAVER CREEK	VOL.	0	0	.0+	.0+	.0+	.0+	.0+	.0+	0.1	.0+
	%	0	0	40	0	40	0	20	0	1	0
FOREST TOTAL	VOL.	1.0	0.3	5.5	0.9	3.0	0.7	0.3	.0+	9.8	2.0
	%	10	15	56	45	31	35	3	5	100	100

[1]Estimates based on RMYLD2 growth and yield projections using incidence and severity data from the survey.
[2]Percentage of District losses in a stand size class.

FIGURE 1. Comparison of DM Incidence between Districts and the trend towards increased infection severity

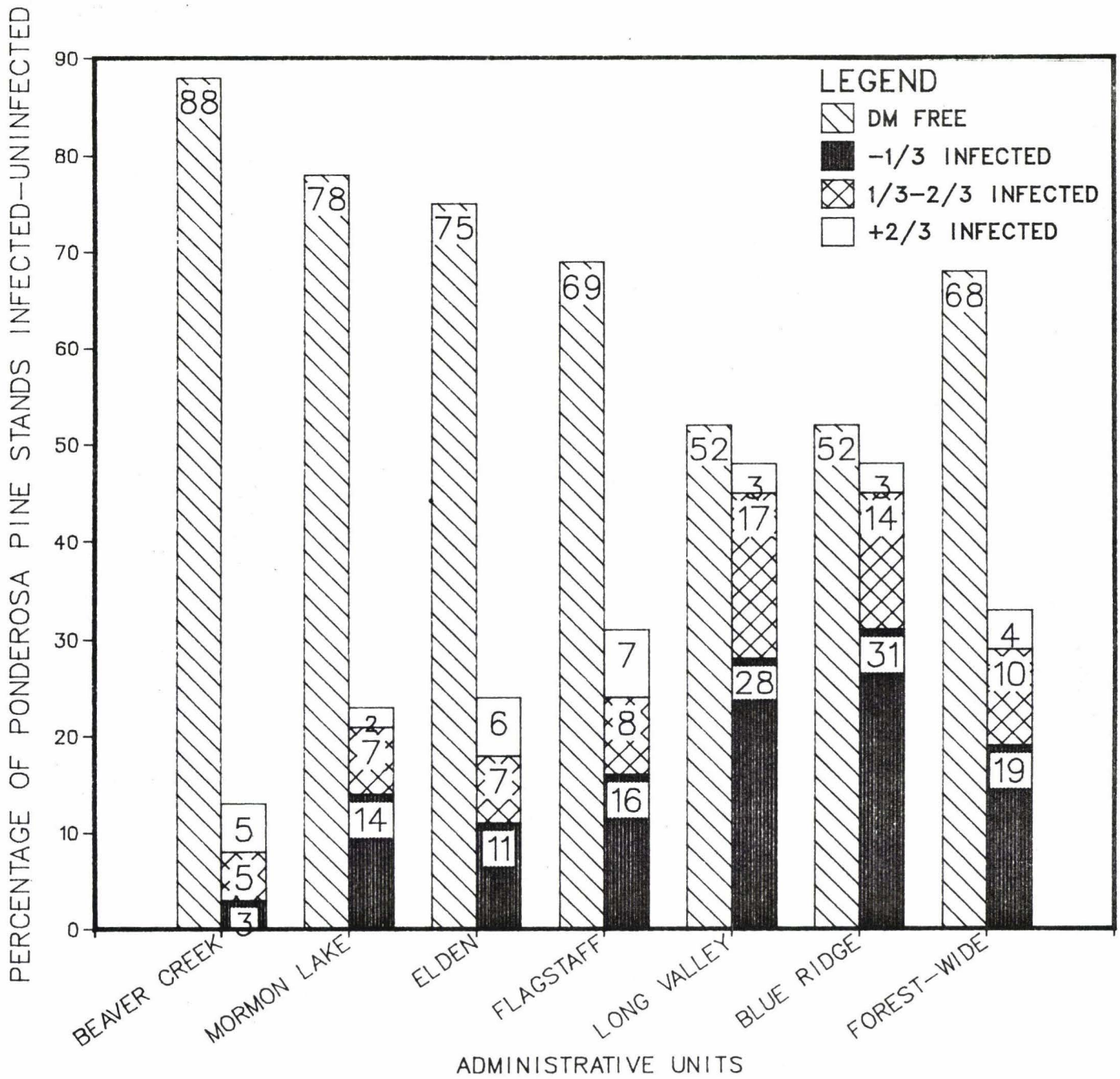


FIGURE 2. Comparison of observed and expected DM incidence by size class for the Coconino National Forest

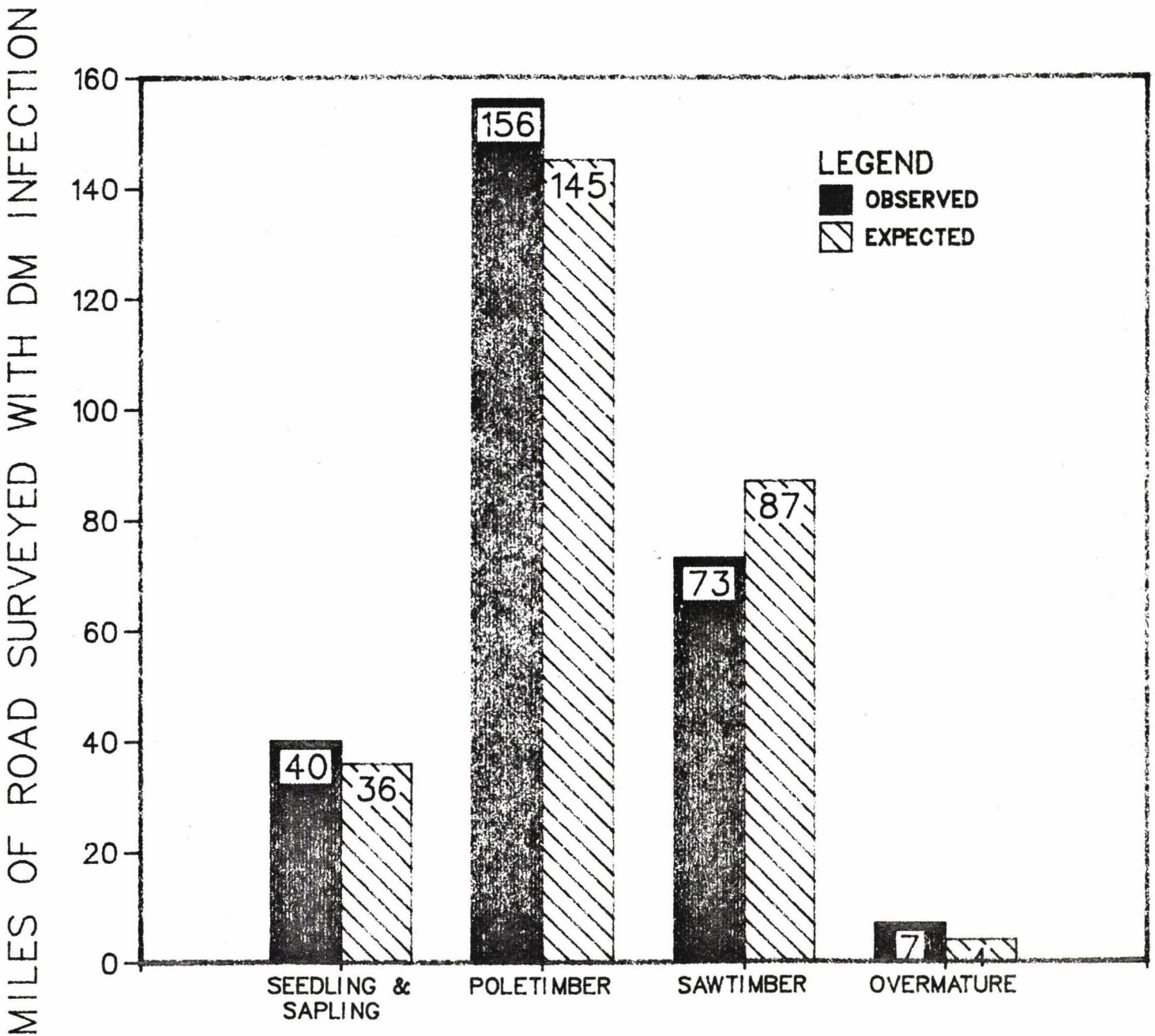


FIGURE 3. Comparison of observed and expected DM incidence by visual quality class for the Coconino National Forest

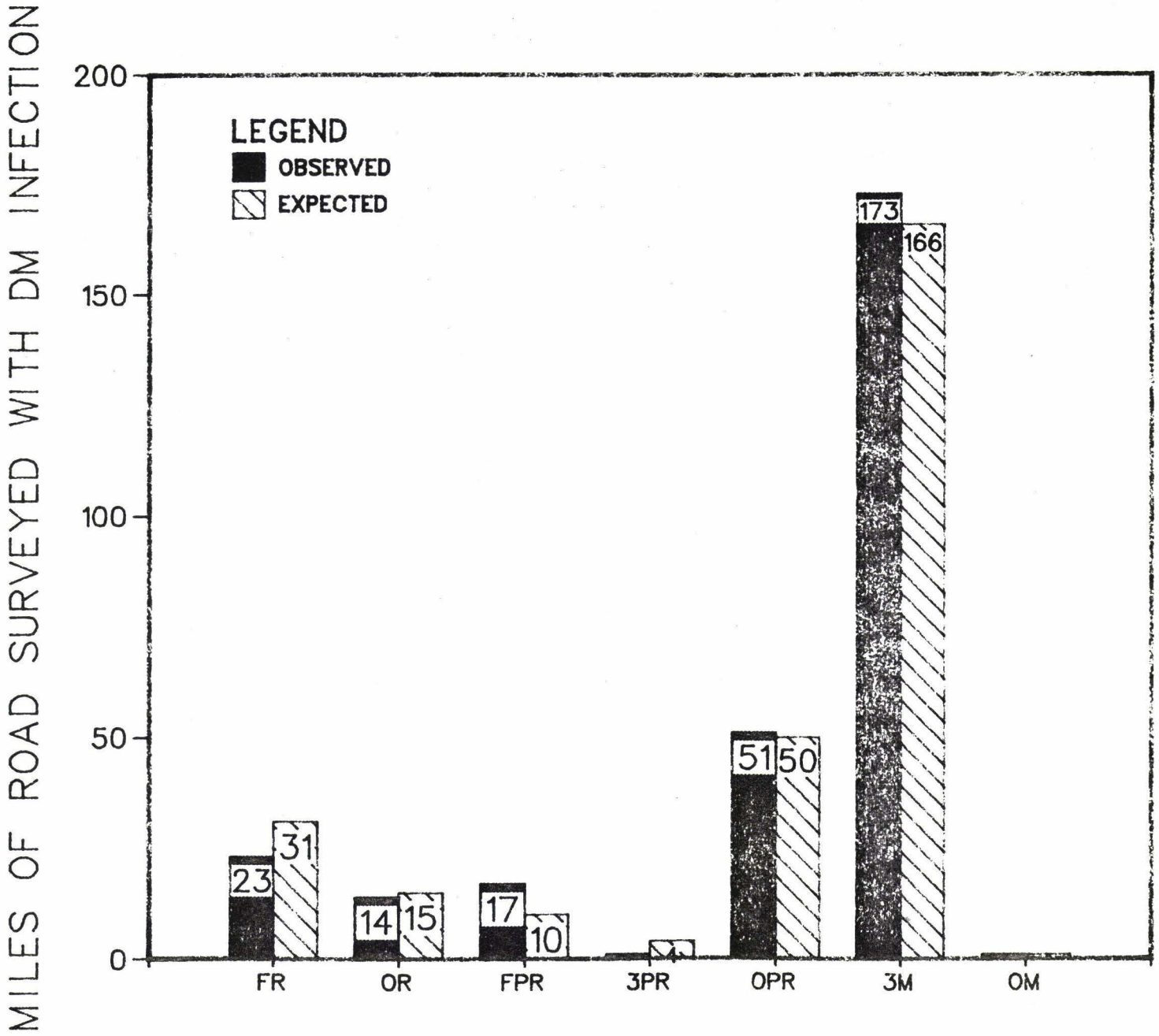


FIGURE 4. Distribution of projected annual volume losses by size class for the Coconino National Forest

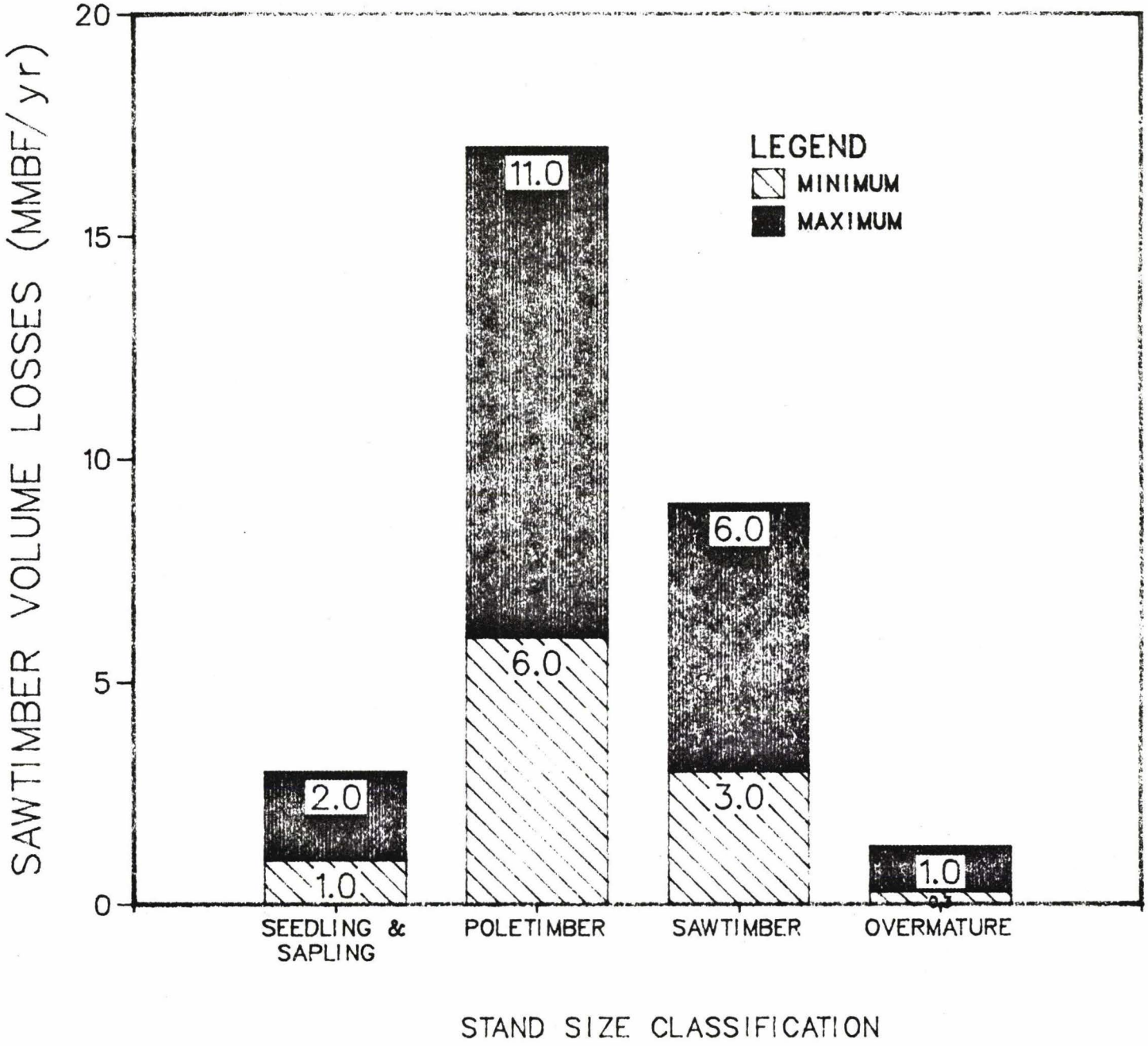
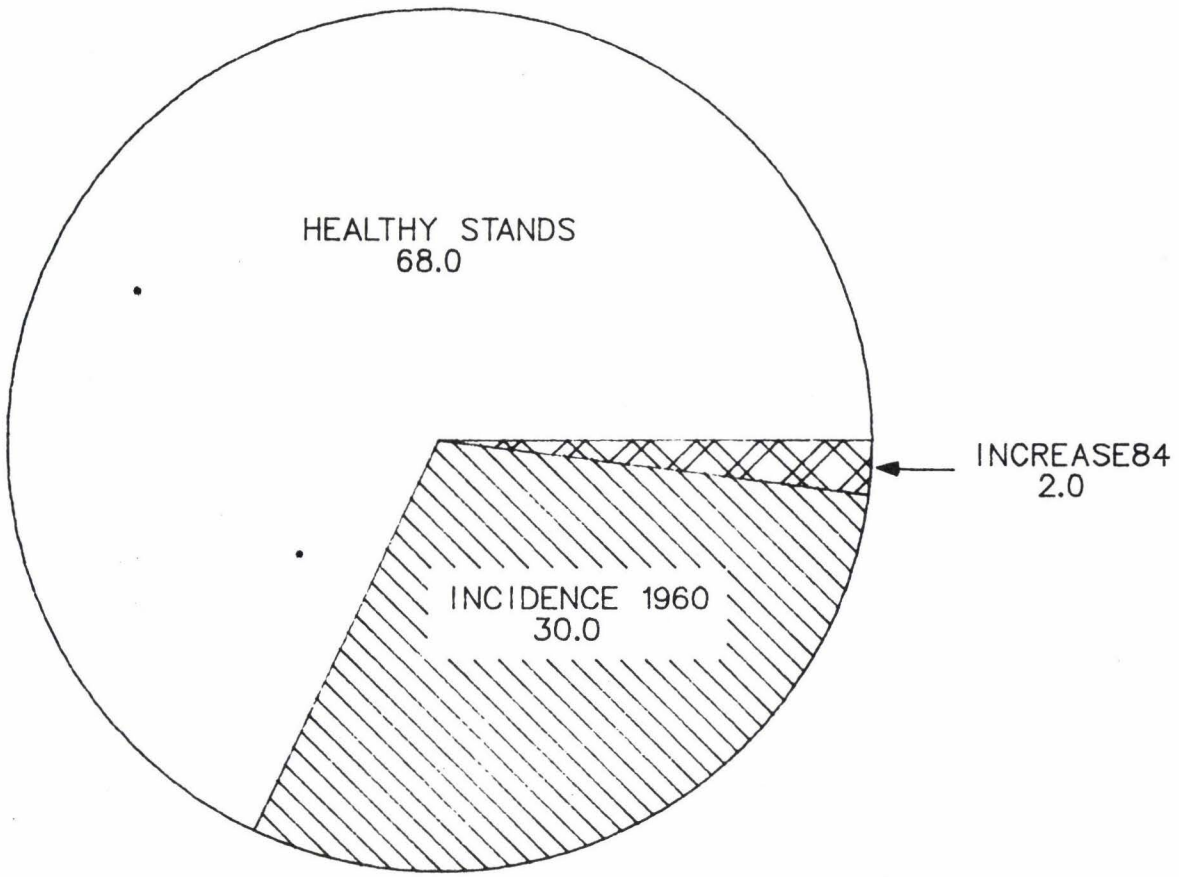
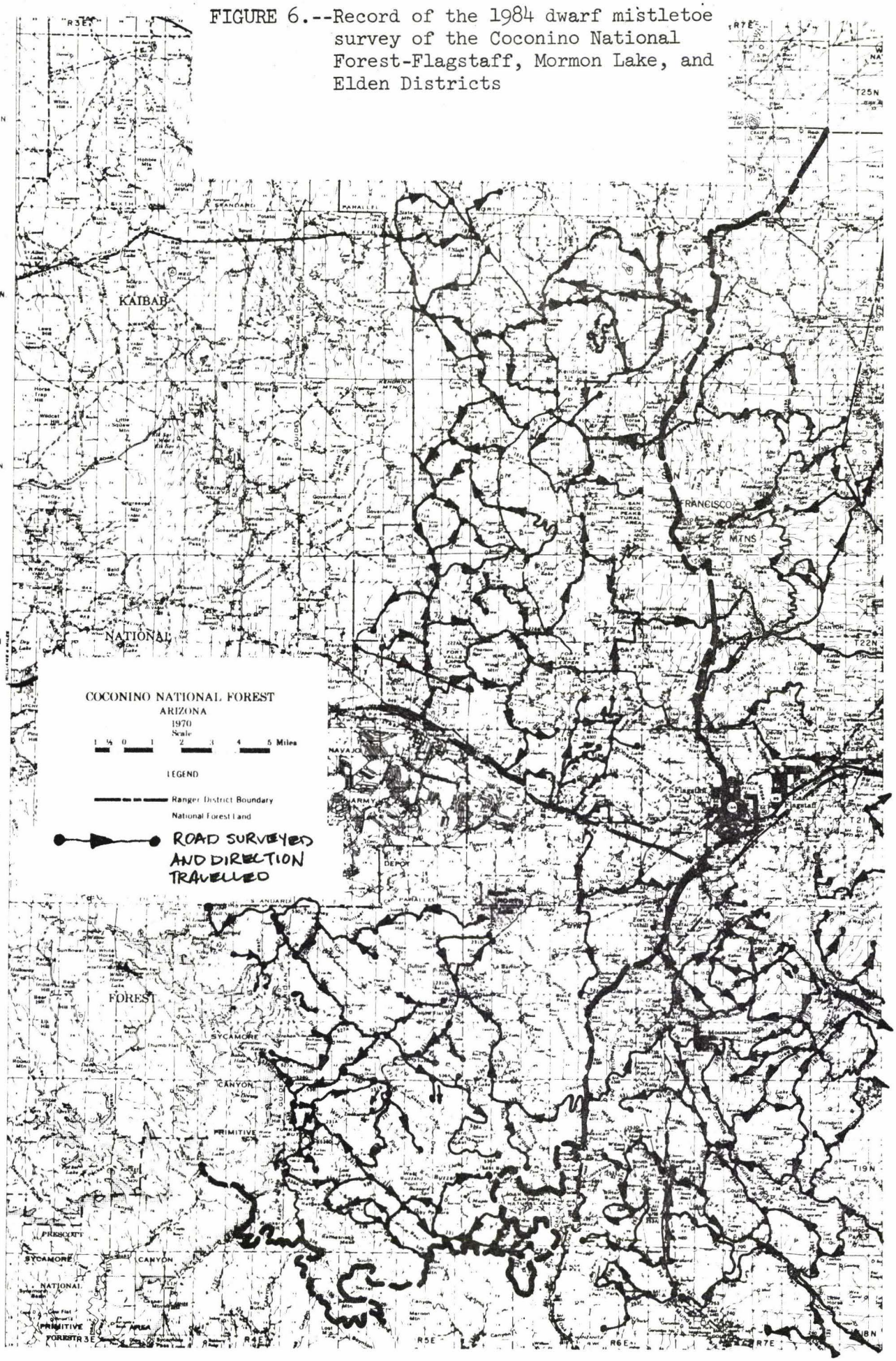


FIGURE 5. Increase in dwarf mistletoe incidence in commercial ponderosa pine stands on the Coconino National Forest from 1960–1984



PROPORTION OF TOTAL NO. OF STANDS

FIGURE 6.--Record of the 1984 dwarf mistletoe survey of the Coconino National Forest-Flagstaff, Mormon Lake, and Elden Districts



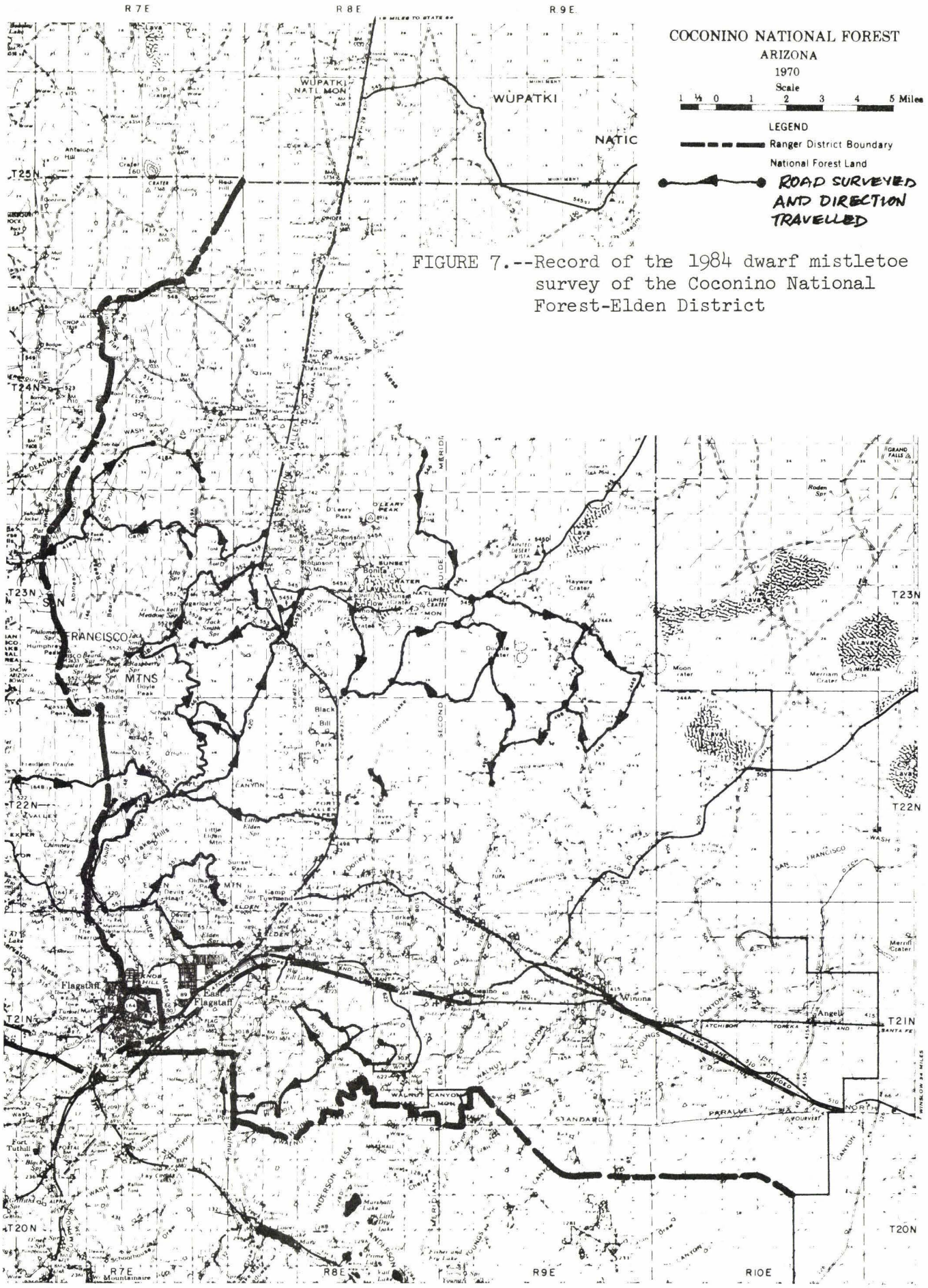
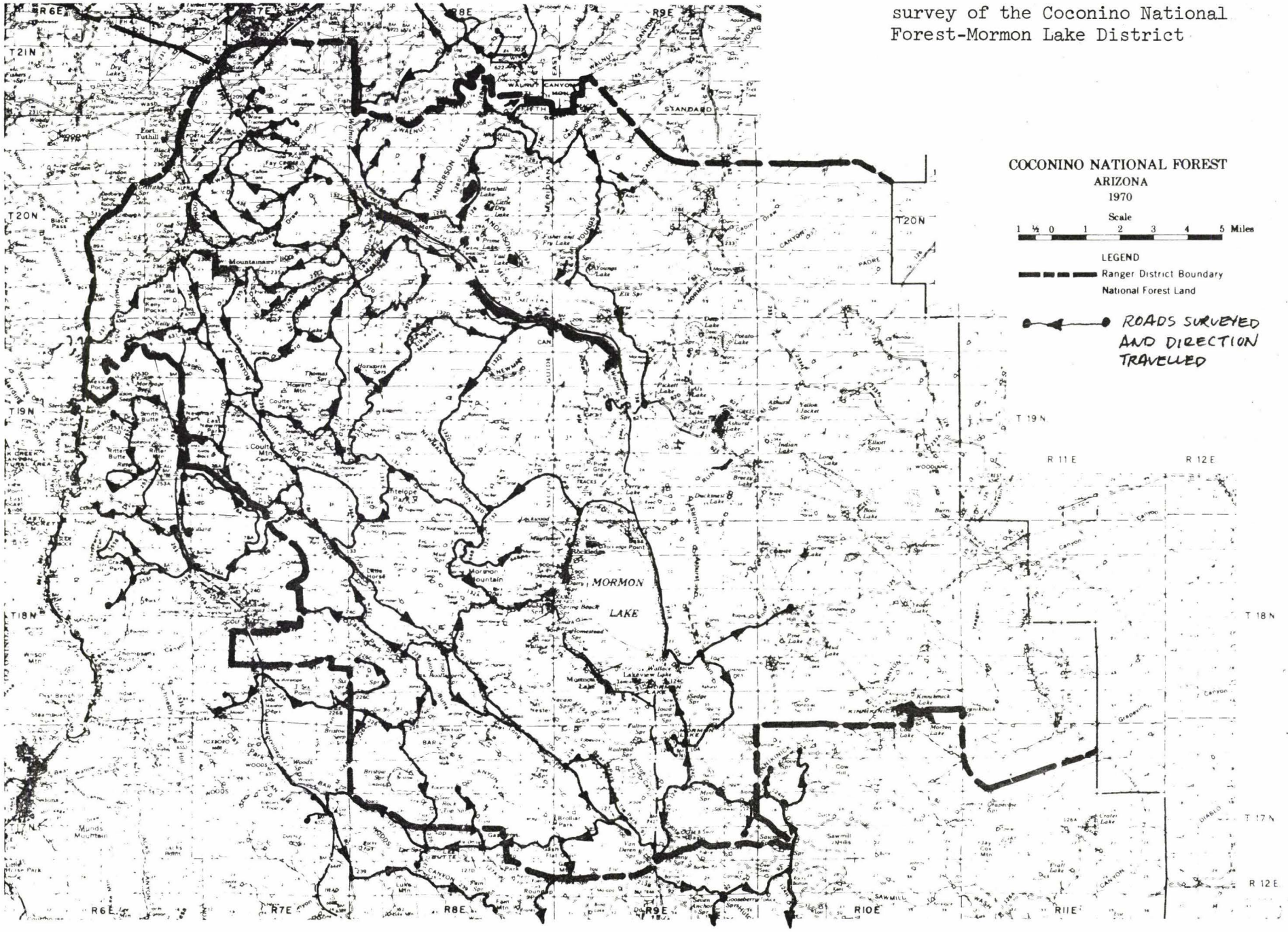


FIGURE 7.--Record of the 1984 dwarf mistletoe survey of the Coconino National Forest-Elden District

FIGURE 8.--Record of the 1984 dwarf mistletoe survey of the Coconino National Forest-Mormon Lake District



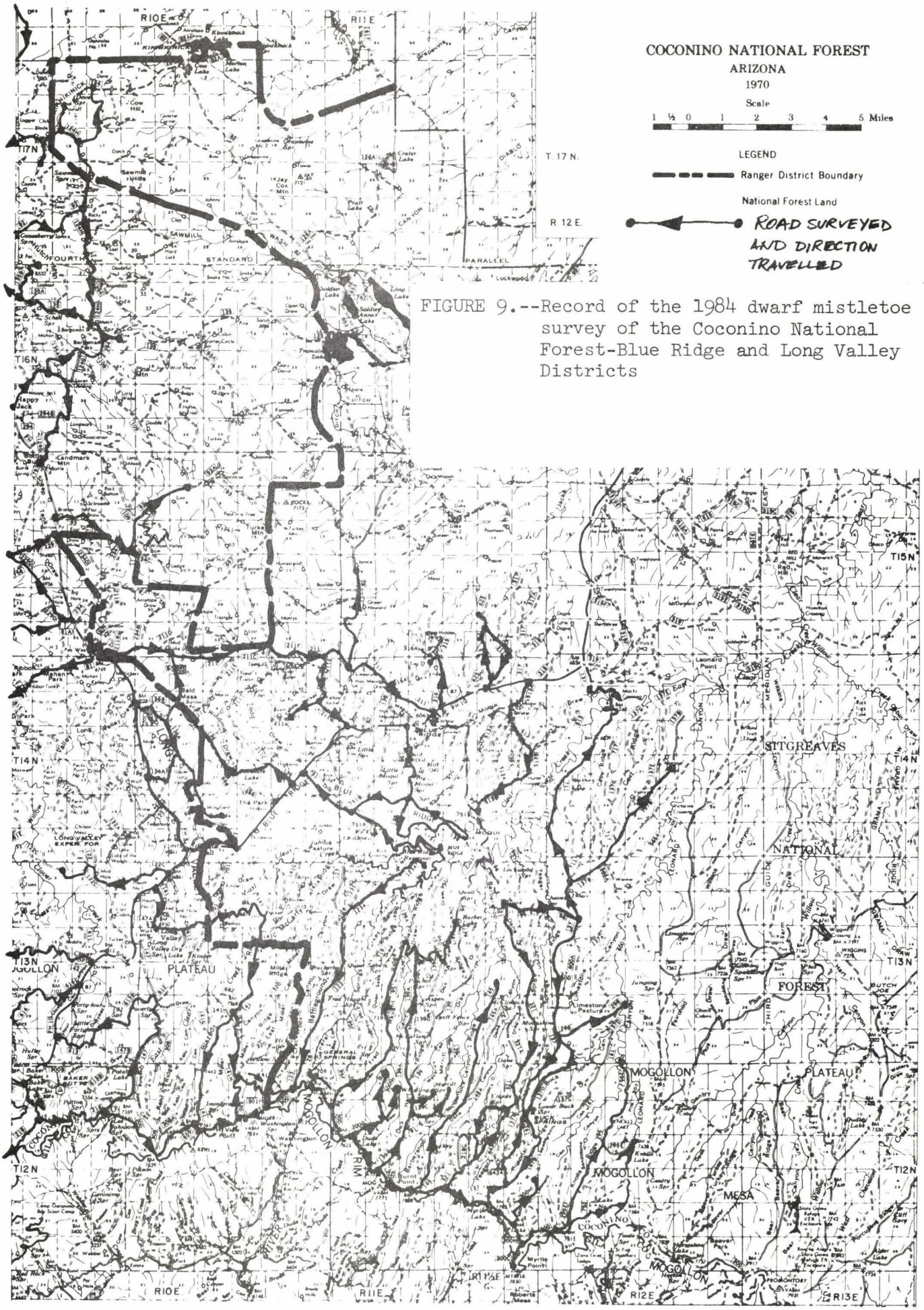


FIGURE 9.--Record of the 1984 dwarf mistletoe survey of the Coconino National Forest-Blue Ridge and Long Valley Districts

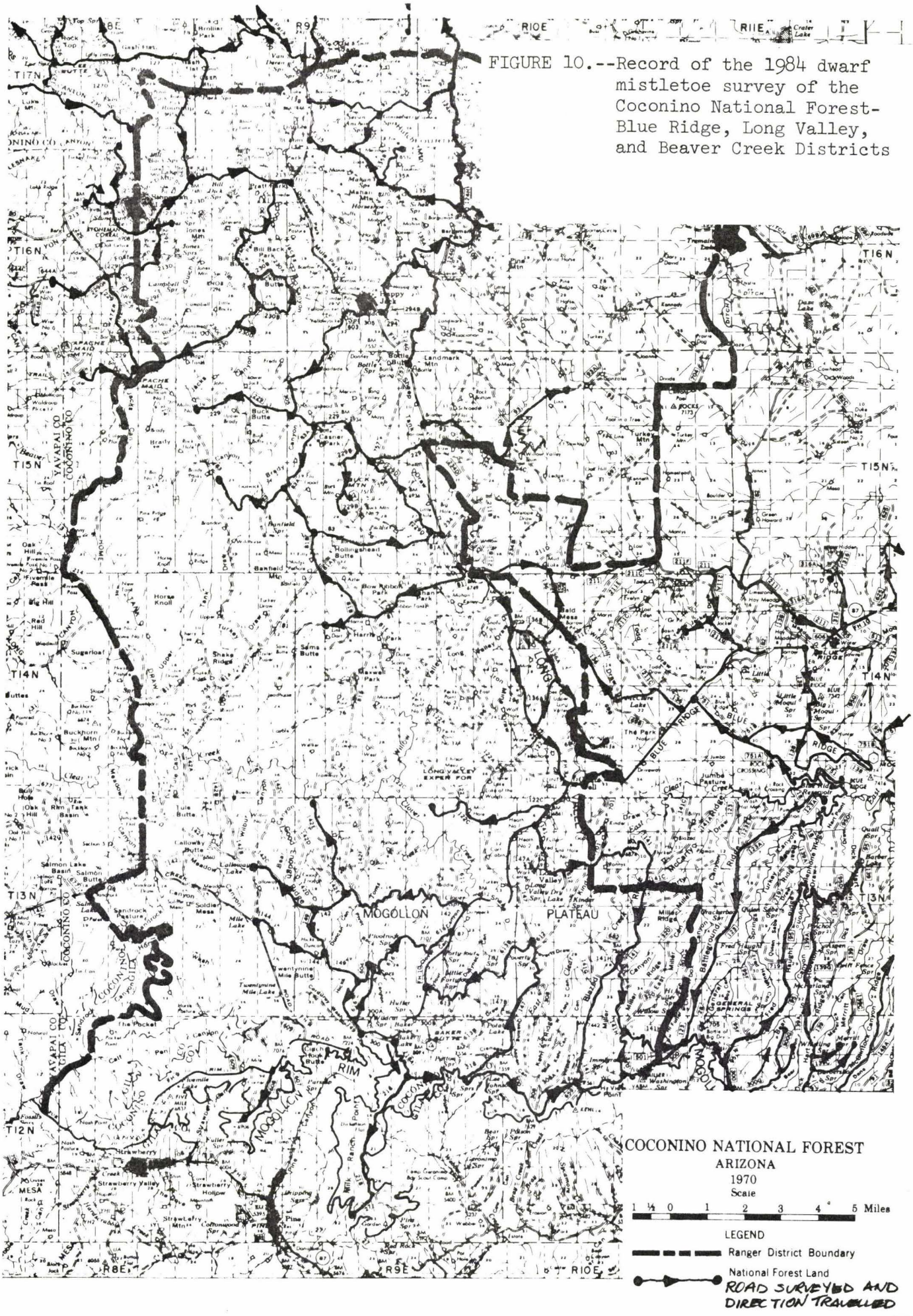


FIGURE 10.--Record of the 1984 dwarf mistletoe survey of the Coconino National Forest-Blue Ridge, Long Valley, and Beaver Creek Districts